CHAPTER 4

COST ESTIMATION

I. General

Cost is defined as the resources that will be consumed if an objective is undertaken. The value of consumed resources is measured by the yardstick of dollars. This makes different cost elements comparable with themselves, as well as with benefits. In addition, because resource value indicates what resources are required for a particular proposed objective, it is a measure of the cost of other objectives that cannot be pursued. Each alternative method of accomplishing the objective will have its own associated cost. Costs include all capital, labor, and natural resources required to undertake each alternative whether they are explicitly paid out of pocket, involve an opportunity cost, or constitute an external cost which is involuntarily imposed on third parties (such as engine emissions, noise, or contaminated water runoff from airports). Costs may be borne by FAA,[1] other governmental units, various components of the flying public, the general public, or some other particular group. Inclusion of all costs borne by all groups is required in order to measure the total value of what must be forgone to undertake each alternative and to avoid errors in answering the economic questions.

An example of the need to consider total cost is that associated with the adoption of a new navigation system. Such systems generally require expenditure by both the signal provider (generally the Government) and the signal user (aircraft operators). Whether or not the system is worth undertaking depends on whether total benefits exceed or equal total costs. Total costs consist of all governmental costs to provide the system and private costs to users to purchase the new avionics. Undertaking the project where benefits exceed only the private or the governmental costs but not total costs would be improper. It would result in the value of resources consumed exceeding the benefits of the system for an overall net loss of value.

[1] FAA costs are frequently characterized by their budget appropriation, including research, engineering and development, facilities and equipment, operations and maintenance, and AIP. While such categorization is useful for various management purposes, it is not necessary for purposes of economic analysis. A cost is a cost irrespective of which appropriation provides for it.

II. Concepts

A. Opportunity Cost

This is the value foregone when resources are shifted from satisfying one objective to satisfying another. An all inclusive "measure," it represents what society as a whole--government and all private groups--must give up to obtain the desired objective. It is the theoretically correct measure of cost for use in economic analyses. As an example, consider an entity with a fixed budget which presently produces benefits from its activities. To undertake a new activity, it must limit or stop completely one or more of its current activities. The opportunity cost of shifting resources to the new activity is the value of the benefits generated by the activity(ies) which must be either limited or terminated.

B. Sunk Costs

These are costs which have already been incurred. The resources represented by these costs have already been consumed and cannot be recovered. As a consequence, they are not relevant for current decisionmaking simply because nothing can be done about them. For example, the decision to add a glide slope to a localizer should be based strictly on the additional benefits and costs associated with the glide slope. The costs of installing the existing localizer and the benefits derived therefrom are irrelevant because they have already been incurred.

C. Out-of-Pocket Costs

These are actual cash outlays. Frequently, they represent only a part of the total cost of a project. Other costs can arise if resources required by a project are already owned by the government. When they are consumed by this project there is an opportunity cost in that they cannot be used in another use, but there is no cash outlay. Care must be taken in the exercise of economic analysis that all costs, and not just out-of-pocket costs, are included.

D. External Costs

These are costs which third parties are involuntarily forced to bear as a consequence of the undertaking of an action by others. Even though these costs impose no cash outlays, they are nonetheless a cost because they consume valuable resources. Noise, engine emissions, and contaminated water runoff from airports are examples.

E. Average Incremental Cost

This measure is an attempt to implement the economist's concept of marginal cost--the increase in total cost associated with a small increase in the production of any particular service or product. Small increases are defined with respect to the infinitesimal changes of the differential calculus or unit of the discrete calculus. In the real world, feasible changes in the size of a project are usually much larger. Average incremental cost is defined as the change is total cost divided by the change in total output over a range that is feasible to achieve.

As an example, the ultimate constraint on airport capacity is the number of runways. When existing runways are operating as efficiently as possible, additional capacity can be obtained only by adding a new runway. An increase of one runway is the feasible change in service level in this case, and average incremental cost is the cost of this runway divided by the total operations that it can handle.

F. Depreciation

Depreciation is a concept used in financial and cost accounting. For accountants, it denotes the periodic allocation of the cost of tangible capital assets over their estimated useful lives. It is a process of allocation, not valuation. While depreciation is important in matching capital costs to the annual revenue stems they generate in order to fairly determine reasonable annual accounting net benefits or income, its use in economic analysis is limited.

Economic analysis is concerned with when resources are consumed and when their benefits occur. Depreciation does not provide such information. Depreciation methodology, however, may have applications in estimating salvage values. To yield reasonable results, such depreciation must relate the asset's age to its actual value. Essentially arbitrary depreciation schemes designed for tax or other purposes must not be used for calculating salvage values.

G. Inflation

The cost of resources consumed and benefits provided are measured by the yardstick of the dollar. This yardstick itself often changes from year to year. The process of a decreasing (increasing) value of the dollar is known as inflation (deflation). For cost or benefit estimates to be comparable from period to period requires that a constant yardstick of value be used. This may be achieved by measuring everything in the dollars of any particular year.

Such estimates are said to be in the constant dollars of a particular year. Estimates where the benefits or costs of any particular year are measured in the dollars of that particular

year are said to be current dollar estimates. The process of converting current dollar values to constant dollar values is explained in detail in Chapter 7.

III. Life Cycle Cost Model

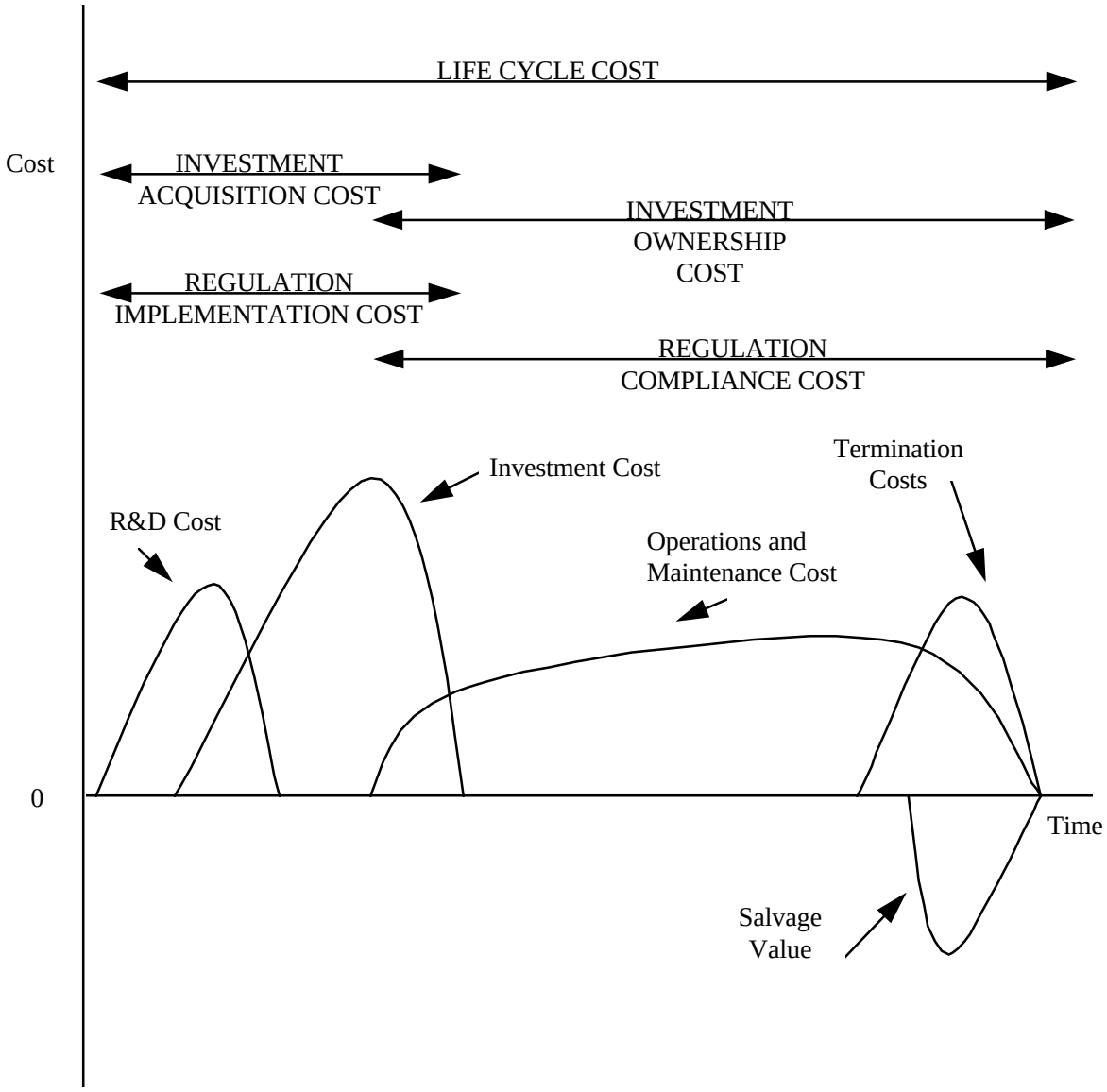
The fundamental cost problem is to determine the total economic costs of proposed governmental actions. Such information is required as input to the decision criteria described in Chapter 5. The life cycle cost model--applicable to both capital investments and regulations--is designed to address this problem by capturing all relevant costs.[2] It organizes costs by when during an activity's life they occur. Costs are classified under four life cycle phases: Research and Development, Investment, Operations and Maintenance, and Termination. Typically, there is an overlap of life cycle phases, but specific costs can be identified with a certain phase based upon the effort they reflect. Figure 4-1 presents an "idealized" summary of major life cycle cost components. Significant variation from this pattern can be expected depending on the characteristics of the specific activity being costed.

As indicated, research and development costs occur first and generally increase every year from project inception up until the beginning of the investment phase, after which they rapidly diminish. Investment costs occur next. They need follow no particular pattern except that they occur over a relatively short period. Operating and maintenance costs rise rapidly following initial investment as facilities and equipment of the project are brought on-line or a regulation is fully implemented. After the investment phase is completed, operating and maintenance costs may continue to rise slowly as a result of increasing equipment age. Near the end of the project life, operating and maintenance costs decline as equipment is retired. Retirement also gives rise to termination costs and salvage value.

[2] The life cycle cost model presented here does not explicitly address external costs. These are often difficult to measure in dollars although they may often be quantified in non-dollar terms. The most significant external cost associated with aviation activities is noise. Techniques for addressing noise reduction (a benefit) are presented in Chapter 3.III.E.1. above. These techniques are equally applicable to addressing noise increases (a cost).

FIGURE 4-1

LIFE CYCLE COST ELEMENTS



Within each phase, particular types of costs typically occur. Recognizing that for organizations which have a large volume of investment programs there is an advantage to having a standard approach to classifying costs, formal cost classification schemes have evolved. Known as work breakdown structures (WBS), the Department of Defense (DOD) pioneered their use with respect to equipment acquisitions. DOD has documented its approach in MIL-STD 881B.[3] Although originally developed with respect to government investment projects, WBS concepts are also applicable, with appropriate modifications, to regulations as well as airport construction projects. Moreover, while their original focus was on the development and investment phases of life cycle cost, the WBS concept may be expanded to include the operations and maintenance and termination phases as well.

The cost categories identified below are deliberately general, being intended to cover many potential situations. For the research and development and investment phases, they are defined with respect to outputs--products to be acquired, constructed, or produced. Costs in the operations and maintenance and termination phases are categorized by function, or input to the production process. Not all cost components identified are relevant to the evaluation of any particular proposed investment or regulation. Moreover, very detailed cost sub-classifications may be appropriate for particular actions, depending on their particular characteristics, which are not specifically identified here.

A. Research and Development Costs

Research and development costs are associated with products requiring development, regulations requiring planning or analysis or mandating purchase of products requiring development, and the planning and design of construction projects including airport projects. They include all costs incurred prior to actually making an investment under evaluation or incurring construction costs, equipment costs, other investment costs, or on-going expenses of complying with a regulation, except those costs that have already been incurred at the time the analysis is undertaken. Incurred costs are sunk costs and are not relevant for decisionmaking purposes. Typical research and development phase costs are:

- Feasibility Analysis
- Environmental Assessment
- Prototype Hardware
- Test Facilities
- Technical Experiments

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[3] *Military Standard--Work Breakdown Structures for Defense Material Items*, *MIL-STD 881-B*, Department of Defense, 25 March 1993.

- Operational Tests
- Construction Project Design and Engineering Plans
- Coordination with Regional Development and Transportation Plans
- System Design and Engineering
- R&D Oriented Software
- Modeling and Simulation
- Regulatory Analysis (prior to issuance of a final regulation)
- Arrangement of Project Financing
- Public Outreach

B. Investment Cost

These are the costs of associated with making a governmental investment, undertaking the cooperating private sector investment associated with a governmental investment, implementing a regulation, or undertaking an airport construction project. They typically include of one or more of the following: land, facilities, equipment, other regulatory implementation costs, and transition costs.

1. Land

Included here are all interests in land that must be acquired: purchases, leaseholds, easements, air rights, mineral rights, etc. Interests in land can be a significant cost for airport projects. Land can also be important for FAA investments. Not only must building sites be acquired to construct new facilities such as the Southern California TRACON, but frequently small parcels must be obtained on which to locate field facilities such as VOR's, marker beacons, or communication facilities. Land that is already owned should not be treated as a sunk cost. Rather it should be valued according to its opportunity cost or market value.

2. Facilities

Facilities consist primarily of buildings and other real property improvements. They may encompass new construction, modifications to modernize or refurbish existing facilities, and leasehold interests. Construction cost should also include any costs to expand, modernize, or refurbish any other part of the facility necessitated by the implementation of the project. Such costs can be significant, particularly with respect to airport construction. When similar facilities are being established in numerous locations, standardized costs may be developed and applied at all specific locations with appropriate modification to reflect

the conditions. For projects with significant unique characteristics, including most airport projects, cost estimates are generally site-specific.

3. Equipment

Equipment consists of items--either developed during the research and development phase or non-developmental commercial off the shelf--required to accomplish an activity other than facilities. Equipment acquisition is characteristic of almost all FAA activities, many regulatory actions, and all airport projects. Moreover, many FAA activities are characterized by not only government purchases of equipment but also require private sector acquisitions of complementary equipment, most notably avionics. Examples of FAA equipment are the non-facility components of VSCS, TDWR, and the agency's aircraft. For private parties, examples are avionics, aircraft equipment, and aircraft instrumentation. And for airport projects, equipment can comprise a wide variety of items ranging from vehicles to security systems. Other items such as furniture or tools would also be classified as equipment.

4. Other Regulatory Implementation Costs

Although regulations can potentially impose any type of investment cost, most regulatory actions will require investments of equipment--described under III. B. 3. above--and/or labor costs. For example, the requirement that all new commercial pilots be instrument rated required candidates to invest in instrument training. And, at the very least a new regulation will require an investment of employee time for affected parties to familiarize themselves with the regulation and establish a system for complying with it. (Such costs may occur when the regulation is initially implemented or be spread out over its life. They are properly classified as investment costs in that for each instance they occur once and then a stream of benefits flow from them. This is in contrast to an expense like refresher training that must be incurred periodically to maintain a particular skill level.)

5. Transition Costs

Transition costs reflect the expense of the impact on ongoing activities caused by building and/or transitioning to a new facility, new equipment, or new procedures (as might be prescribed by regulation). This impact can be very small as in the case of a minor regulation-driven change requiring a few hours of employee time to accommodate. Or it can be very large such as with a construction project at a major airport that leads to the temporary closure of major facilities of an airport. For example, a runway reconstruction project could lead to the total or partial closure of the runway itself, and may cause the temporary closure of any runway intersecting it. Disruption and delay associated with the

project might result in millions of dollars of additional costs to airlines, general aviation users, passengers, and others using the airport.

Frequently, FAA investment projects incur significant transition costs. This occurs because service cannot be disrupted requiring that new equipment and sometimes facilities must be put in place and be made operational before changing over to the new system. Moreover, because many FAA investments require cooperating investment from the private sector, such as the purchase of new avionics, two otherwise redundant systems must be operated while the private sector has time to make the required new investment.

C. Operations and Maintenance Costs (O&M)

These are the ongoing costs required to operate and maintain a proposed investment project or remain in compliance with the proposed regulation. These costs may occur continuously, annually, or periodically every so many years. These costs are typically grouped into functional or input based categories. The following list includes most of these costs.

- Personnel Costs: These must be incurred to both operate and maintain any investment or comply with many regulations. A major component of ongoing costs, they include all compensation paid to employees, including benefits and paid absences, as well as compensation paid to employees during recurring training and during travel time.

- Consumables: These are the costs of all materials consumed in the operation or support of equipment. Examples of some typical materials are oil and lubricants, copier paper, toner, paper rolls and tapes, magnetic recording tape, and photographic supplies.

- Energy and Utilities: Included here are the costs of electricity, gasoline, diesel fuel, natural gas, water, etc.

- Facilities: Consists of the ongoing costs to provide facilities and equipment such as real property lease payments and equipment lease payments.

- Telecommunications: Consists of the cost of communications services procured from another organization. Examples are commercial and FTS telephone service or satellite communications. Not included within this category are telecommunications services produced within the system being costed; these are captured through equipment acquisition and rental costs, personnel costs, utilities cost, etc.

- Computer Service Costs: Consists of the costs of computer services purchased from others. As with telecommunications costs, this category does not include computer services produced within the system being costed; these enter through equipment acquisition and rental costs, personnel costs, utilities cost, etc.

- Spares and Support Equipment: Replenishment spares indicate the recurring costs of inventory replacement. (Inventory already purchased as initial spares and repair parts is not included.) Replacement support equipment represents the ongoing cost associated with maintaining sufficient quantities of peculiar and common support equipment.

- Packaging, Handling, and Transportation: Represents the cost of packaging, handling, transportation of spares, repair parts, and other material between supply points and equipment to be maintained.

- Recurring Training: This indicates training costs to maintain operations and support employees' skills and to train new employees needed to replace departing employees. For current employees, this category includes training, specific travel costs, and FAA Academy cost. For replacement employees, it also includes compensation during training.

- Recurring Travel: This item represents the direct costs of travel and transportation necessary to operate and support a project. It consists of such items as airfares, subsistence payments, lodging, and depreciation and operating costs of vehicles. It does not include wages or salaries paid to employees while in travel status; these are defined to be included in personnel costs above.

D. Termination Costs

- Dismantling Costs: These are the costs, if any, required to dismantle, disassemble, remove, and dispose of old buildings, equipment, spare parts, etc. at the end of an investments lifetime.

- Transportation and Packaging: These are the costs, if any, required to package and ship old equipment, spare parts, etc. after dismantling.

- Site Restoration: This is the cost, if any, to restore the site on which the old equipment was located to its original or near original condition. It may involve grading of earth, reforestation, or landscaping.

- Storage of Material Management: This is the cost to store, maintain, and manage equipment, spares, etc. which are removed from a site but not yet disposed of.

E. Salvage Value

Salvage value is the value, if any, of the investment equipment at the end of its expected life. It is treated as an offset to termination costs.

IV. Selected Cost Estimation Topics

Cost estimation is a diverse discipline in and of itself and apart from benefit-cost analysis. A systematic treatment of it is beyond the scope of this guide.[4] However, certain topics of particular use to FAA analysts are treated in this section.

A. Work Breakdown Structures

For organizations like FAA which have a large number of facilities and equipment acquisition programs, there is a distinct advantage to having a standard approach for describing those acquisitions. A work breakdown structure (WBS) provides such a structure upon which to build the management information system necessary to support technical and financial needs of acquisition programs. Historically, WBS's have been utilized with respect to the research and development and investment phases of acquisitions. Conceptually, the WBS approach can be expanded to include airport investment costs and regulatory implementation costs as well as other elements of life cycle cost. By providing all parties with a common reference in describing the system, it serves as a framework against which a project's costs may be estimated, budgeted, and reported. It can be a primary reference in identifying project elements and of insuring that all portions of the project are captured in the cost estimate.

The Department of Defense (DOD) pioneered the use of the WBS for equipment acquisitions (including research and development and investment costs). The WBS is a

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[4] A useful treatment of life cycle cost estimation with respect to FAA acquisitions is presented in *FAA Cost Estimating Handbook*, ASU-305, 1997.

method of diagramming the way work is to be accomplished. The diagram separates the work content into "elements". These elements reflect the prime mission product (PMP) together with other elements such as support equipment, data, training, and spares that constitute the total system. It is important to realize that the WBS is product or output oriented, as opposed to having a functional or input orientation. Product orientation allows managers to better focus on management problems that are impacting the product, the deliverable system.

Military Standard 881B contains WBS outlines for various types of systems, such as aircraft, missiles, electronics, tanks, ships, and recently, simulators. The Military Standard breaks these systems down into three summary levels, defining elements of detail at each level. It does not define level 4 elements, recognizing that these need to be constructed to reflect the specific characteristic of particular acquisitions. Electronics systems are of primary applicability to the FAA. An example of the WBS for an electronic/automated software system is shown in Table 4-1. Appropriately adapted, this structure may be useful in building frameworks against which to estimate research and development and investment costs for many FAA facility and equipment acquisitions, certain regulatory actions, and certain airport equipment investments.

TABLE 4-1

SAMPLE WBS for an ELECTRONICS SYSTEM

Level 1: Electronic/Automated Software System	
Level 2	**Level 3**
Prime Mission Product (PMP)	Subsystem 1...n (Specify Name) PMP Applications Software PMP System Software Integration, Assembly, Test and Checkout
Platform Integration	
Systems Engineering/Program Management	
System Test and Evaluation	Development Test and Evaluation Operational Test and Evaluation Mock-ups Test and Evaluation Support Test Facilities
Training	Equipment Services Facilities
Data	Technical Publications Engineering Data Management Data Support Data Data Depository
Peculiar Support Equipment	Test and Measurement Equipment Support and Handling Equipment
Common Support Equipment	Test and Measurement Equipment Support and Handling Equipment
Operational/Site Activation	System Assembly, Installation and Checkout on Site Contractor Technical Support Site Construction Site/Ship/Vehicle Conversion
Industrial Facilities	Construction/ Conversion/ Expansion Equipment Acquisition or Modernization Maintenance (Industrial Facilities)
Initial Spares and Repair Parts	

The following provides summary definitions for the Level 2 items in Table 4-1. Detailed definitions may be found in Appendixes B and H of MIL-STD 881B.

- Prime Mission Product (Hardware and Software): This element identifies the cost of those subsystems--hardware and software--designed to accomplish program mission (as opposed to supporting the program's mission). Any system engineering, program management, data, or testing such as factory acceptance testing, which can be specifically identified with a subsystem (as opposed to the system as a whole) is included in the cost of the subsystem in this element of cost. Also included as separate subelements of this item of cost are system integration and assembly, hardware/software integration and test, and first destination transportation.

- Platform Integration: This element includes the cost of all engineering and technical efforts provided to the platform manufacturer or integrator directly associated with installing the product into a host vehicle (if any).

- Systems Engineering/Program Management: This item indicates the systems engineering and technical control as well as the business management of particular projects. (Note that, if system/program management can be associated with a specific subsystem or piece of hardware/software, it is typically included in the subsystem cost as part of Prime Mission Product.)

- System Test and Evaluation: This element indicates the detailed planning, conduct, support, data reduction, and reporting on the use of prototype or production hardware/software to obtain or validate engineering data on the performance of the system. (Note that, if the test can be associated with a specific subsystem or piece of hardware/software, the test is not systems test but is a subsystem test and should be included in Prime Mission Product as part of the subsystem cost. Moreover, acceptance testing during production and/or installation is not part of this element but rather is included as part of Prime Mission Product.)

- Training: This element identifies the cost of training services, devices, accessories, aids, equipment, and parts used to facilitate instruction through which personnel acquire concepts and skills to operate and maintain the system. It encompasses all costs of designing, developing, and producing training programs, and training the initial instructors as well as the first generation of personnel who will maintain and operate the system.

- Data: This cost element indicates the effort required to record and preserve information concerning the new system. It includes technical publications, engineering data, management data, and support data.

- Peculiar Support Equipment: This element identifies those items required to support and maintain the system but not directly engaged in the performance of its mission. The term "peculiar" indicates that the item is not stock listed or maintained within an accessible inventory.

- Common Support Equipment: This element identifies those items required to support and maintain the system but not directly engaged in the performance of its mission. The term "common" indicates that these items are stock listed or maintained within an accessible inventory.

- Operational/Site Activation: This element refers to the real estate, construction, conversion, utilities, and equipment to provide all facilities required to house and serve prime mission product at the organizational and intermediate level, except for turnkey operations. It includes contractor technical support, site construction, site conversion, and on site system assembly, installation, and checkout.

- Industrial Facilities: this element refers to the construction, conversion, or expansion of industrial facilities for production, inventory, and contractor depot maintenance required when that service is for the specific system.

- Initial Spares and Initial Repair Parts: This element consists of the spare components, assemblies, subassemblies, and materials to be used for replacement purposes in major end items of prime mission product. This element excludes test spares (included in systems test element of cost) and spares provided specifically for use during system installation, assembly, and checkout on site (included in operational site activation).

B. Cost Estimation Techniques

There are several general approaches to actually making cost estimates. The three most widely recognized are: the parametric method, the analogy method, and the grass roots method. In addition, two other approaches can be identified: the component part method and the vendor bid method. When choosing an estimating methodology, the estimator must keep in mind that cost estimating is a forecast of future costs based on a logical extrapolation of currently available data. Selection of a method to estimate any particular cost element is influenced by a number of factors including the type of investment or program (hardware, software, regulation, etc.), life cycle cost element (research and development, investment, operations and maintenance, etc.) to be estimated, the life cycle phase a program has actually reached, and data availability.

- The parametric method estimates costs based on various characteristics or attributes, called parameters, of the system being costed. It depends on the establishment of a functional relationship between system costs and these parameters. Such relationships, known as cost estimating relationships (CER's), are typically estimated from historical data using statistical techniques. Examples would be estimating costs as a function of such parameters as equipment weight, vehicle payload or maximum speed, number of units to be produced, or the number of lines of software code to be written. This method is applicable to all types of investments and programs, to all elements of life cycle cost, and at any point in a programs life cycle.

- The analogy method estimates the cost of a new system by taking the cost of a similar existing one and adjusting it to reflect the differences between the two systems. This adjustment can be made either analytically or judgmentally. The analogy method is applicable to all elements of life cycle cost at any point in a program's life cycle. Because it depends on a comparison with an existing system or program, its application with respect to radically new systems or programs, particularly those embodying significant technological advances, is limited because relevant analogies do not exist.

- The grass roots method, also known as the piece part or industrial engineering method, estimates cost by developing a detailed list of parts. The cost of each of these parts is then determined and the costs of the parts are summed to determine total parts cost. Assembly and/or manufacturing costs and overhead costs are added to total parts cost to yield total cost. The grass roots method is primarily applicable only to hardware production. Moreover, because it requires detailed specifications for the items to be procured, it is not suitable for use early in the research and development phase of a program. Properly executed once detailed specifications for the items to be procured are developed, it can yield more precise estimates than either the parametric or analogy methods.

- The component part method is similar to the grass-roots method but proceeds at a more aggregate level of detail. It determines cost by summing the costs of all components (as opposed to the parts which comprise components) which are known. Components for which costs are unknown are estimated by one of the other cost estimating methods and added to the sum of known costs. Finally, assembly and overhead costs are added to obtain total cost. Like the grass roots method, the component part method is primarily applicable only to hardware production once specifications have been developed.

- The vendor bid method utilizes the cost proposals or bids submitted by vendors in response to a request for production proposals. Use of this method is limited because cost estimates are usually required prior to receipt of bids. However, previously

developed contractor estimates may be utilized at times, provided they are judged and found to be reasonable.

C. FAA Cost Estimation Factors

A common technique for estimating certain elements of development and investment phase costs is to calculate them as a percentage of prime mission product hardware and software costs. This approach requires that estimates for prime mission product first be developed and that appropriate percentages be available. The Office of Aviation Policy and Plans has developed such percentages, calibrated to FAA experience, by which development and acquisition cost estimates can be developed once the cost of the prime mission product hardware and/or software components is known.[5] Table 4-2 presents a summary of FAA cost factors by work breakdown structure element.

[5] The results are documented in APO Bulletin, APO-88-2, "Federal Aviation Administration (FAA) Cost Factor Study," May 1988.

TABLE 4-2

FAA COST FACTORS SUMMARY

All Factors Are Presented As A Percentage of Prime Mission Product Cost
(Less Integration and Assembly Cost)

WBS		Communications FAA Factors		Radars FAA Factors		Electronics FAA Factors		Systems Composite FAA Factors	
Level	Element	R&D	ACQ	R&D	ACQ	R&D	ACQ	R&D	ACQ
3	Integration & Assembly	23.7	27.9	12.3	10.0	10.2	-	15.5	15.1
2	Training	0.5	2.8	0.7	-	-	0.7	0.6	1.8
2	Peculiar Support Equipment	33.6	5.8	1.2	9.6	12.0	7.0	10.4	5.4
2	Installation & Test	-	18.0	-	-	-	-	-	18.0
2	Systems Engineering/ Program Management	55.0	31.9	30.8	13.3	32.0	11.7	40.1	18.0
2	Data	9.0	4.4	22.8	4.6	24.0	6.4	20.9	4.5
2	Site & Facilities	2.2	7.2	46.0	21.4	47.0	15.3	24.3	12.7
2	Common Support Equipment	8.0	3.0	-	-	-	0.8	0.8	2.5
2	Initial Stock	0.8	37.0	16.5	7.0	38.5	22.0	18.6	15.2
2	Test & Evaluation	21.5	9.5	18.6	8.3	14.8	5.2	17.1	6.6
2	Industrial Facilities	-	-	-	2.0	14.0	-	14.0	2.0

D. Utilities

Utilities expenses include the costs of electricity, natural gas, water, etc. These costs are typically computed by multiplying a cost per unit by the units to be consumed. Energy consumption needs of new equipment for the initial year of implementation should be based on current experience for existing or analogous systems and engineering estimates for new systems. Future estimates should be made by adjusting initial year estimates for anticipated future experience. Other regular utility costs related to general facilities and not specific equipment are more of an overhead nature and typically have an established

pattern of usage. Tables 4-3 and 4-4 provide a recent history of the average retail prices of electricity and natural gas, respectively. Additional information can be obtained on the Internet at http://www.eia.doe.gov/price.html.

TABLE 4-3

AVERAGE RETAIL PRICES of ELECTRICITY SOLD by ELECTRIC UTILITIES
(Cents per kilowatt-hour)

	1991	1992	1993	1994	1995	1996
Residential	8.05	8.23	8.34	8.41	8.42	8.39
Commercial	7.51	7.63	7.72	7.75	7.70	7.63
Industrial	4.85	4.84	4.86	4.72	4.69	4.60
Other	6.43	6.66	6.86	6.79	6.70	6.72
Total	6.75	6.83	6.92	6.92	6.90	6.87

Source: Energy Information Administration, U.S. Department of Energy

TABLE 4-4

AVERAGE RETAIL PRICES for NATURAL GAS
(Dollars per thousand cubic feet)

	1991	1992	1993	1994	1995
Residential	5.82	5.89	6.16	6.41	6.06
Commercial	4.81	4.88	5.22	5.44	5.05
Industrial	2.69	2.84	3.07	3.05	2.71
Vehicle Fuel	3.96	4.05	4.27	4.11	3.98
Electric Utilities	2.18	2.36	2.61	2.28	2.02

Source: *Natural Gas Annual 1995*, Energy Information Administration, U.S. Department of Energy, Nov. 1996, p. 5

E. Personnel Cost

Personnel costs can be a major component of the ongoing costs of an investment or of complying with a regulation. They may be estimated as the product of the quantity of

labor required and the total compensation paid per unit of labor. Labor requirements are typically measured in full time equivalent work (FTE) years and compensation as total annual compensation per FTE per year.

1. Hourly Labor Requirement

The first step in computing personnel costs is to determine the annual labor hours required by type of skill and by pay level. This should be done separately for government employees and private sector employees. For government employees, a further distinction should be made between permanent, temporary, and intermittent employees. (These distinctions are necessary because different fringe benefit and annualization factors apply for different groups). Hours requirements should include not only direct labor, but such other items as recurring training, travel time, break time, supervisor time, staff support time, other overhead staff time, etc.

Labor requirement estimates for new systems or regulations can be developed based on engineering data or previous experience with similar types of undertakings. For existing ones, estimates can be based on actual experience. A potential data source for many existing FAA systems is the FAA's staffing standards.[6] The staffing standards are detailed models relating required staffing to the volume of work required to be done. Each contains information on the staff required to provide specific services or maintain specific equipment. While potentially very useful, the analyst is cautioned to carefully screen staffing standard data for suitability for the analysis at hand. At times, it may contain assumptions or procedures which are inappropriate for benefit-cost analysis.

2. Conversion to Full Time Equivalents (FTE's)

The next step is to express hourly labor requirements on an FTE basis. For hours to be worked by permanent and temporary government employees, this requires that the required labor hours by each skill and pay level be divided by the actual number of hours *worked* per year by a full time employee. Dividing by hours actually *worked* rather than by *hours paid* for a full time work year adjusts for all leave usage and holidays. For FAA employees, a precise estimate of this number of hours may be obtained from the Office of Financial services (ABA) and the Office of Human Resource Management (AHR).

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[6] *Air Traffic Staffing Standards Systems*, FAA Order 1380.33B, March 10, 1980; *Airways Facilities Sector Level Staffing Standard System*, FAA Order 1380.40C, December, 21, 1992; *Staffing Standards--Flight Standards Field Regulatory Programs*, FAA Order 1380.28A, November 1975; *Regional Logistics Division Staffing Standards*, FAA Order 1380.42A; *Staffing Guide--Aviation Safety Inspectors (Manufacturing)*, FAA Order 1380.49A, May 1995.

Information may also be found in the various staffing standards. For most estimates involving government employees, however, a government-wide representative value may be used.[7] For hours to be worked for all classes of government employees other than intermittent workers (also known as paid when actually employed or WAE employees), a value of 1776 hours may be used.[8] For private sector employees--including government contractors--actual data should be used where available. Where unavailable, annual hours required should be divided through by 1902 hours assuming utilization of full time employees, 2017 hours assuming utilization of part time employees, or 1916 hours if the breakdown between full time and part time employees is unknown.[9]

3. Total Compensation per FTE

Third step is to determine total compensation per FTE. It is estimated as the sum of four components: the annual stated compensation, other compensation subject to fringe benefits, fringe benefits, and other pay.

- Annual Stated Compensation: FAA employees are paid with respect to either the FG (General Schedule or GS before personnel reform) or FW (Federal Wage Scale or WG before personnel reform) pay scales. Stated compensation for FW employees is expressed directly in hourly rates which must be annualized by multiplying by 2087--the number of paid hours in a full time work year. FG compensation is expressed in annual salaries. Private sector employee stated compensation rates can be determined based on FG or FW compensation rates for equivalent skills or other data which may be available on a case by case basis. For project or regulation evaluation purposes, compensation levels associated with FG step 5 and FW step 3 should be used.

- Other Compensation Subject to Fringe Benefits: If the project or regulation involves labor requirements that will generate compensation subject to fringe benefits, discussed below, such as premium pay for air traffic controllers, location pay, or night differential and weekend pay for certain employees, this should be identified and added to the stated compensation rate to the extent it is expected to occur.

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[7] *Performance of Commercial Activities*, Revised Handbook to OMB Circular No. A-76, March 1996, p. 20.

[8] FAA employees relatively few WAE workers. Should it be necessary to compute FTE's for these workers, guidance should be sought from AHR. Before personnel reform, required hours could be annualized by dividing by 2007--reflecting that WAE workers accrued no leave but were paid for official Federal holidays. This could change under personnel reform.

[9] *Statistical Abstract of the United States*: 1996, Table 669.

- Fringe Benefits: Fringe benefits are additional compensation provided to employees. They may be computed as the product of an appropriate factor and the sum of annual compensation and other compensation subject to fringe benefits. Fringe benefits are grouped into four categories: retirement and disability, health and life insurance, Medicare, and other benefits. Current government-wide factors for each are indicated in Table 4-5 for permanent employees under the Civil Service Retirement System (CSRS) or Federal Employees Retirement System (FERS), temporary and intermittent Federal employees, and for private sector employees. The factors given for private sector employees are an average for the overall private sector. Because benefits vary widely in the private sector, more specific data should be used when estimating effective compensation levels for specific private sector employees when such data is available.

TABLE 4-5

FRINGE BENEFIT FACTORS

Category	Permanent Government	Temporary and Intermittent Government	Private Sector
Retirement and Disability:			
General	23.7%	6.20%	10.3%
Air Traffic Controllers	32.3%		
Law Enforcement/ Fire Protection	37.7%		
Health and Life Insurance	5.6%		7.1%
Medicare	1.45%	1.45%	1.45%
Miscellaneous	1.7%		4.6%

Source: *Performance of Commercial Activities*, Revised Supplemental Handbook to OMB Circular No. A-76, March 1996, p. 20. Employee Benefit Research Institute (EBRI) 1994 data.

The standard retirement cost factor represents the federal government's complete share of the weighted CSRS/FERS retirement cost to the government, based upon the full dynamic normal cost of the retirement systems; the normal cost of accruing retiree health benefits based on average participation rates; Social Security, and Thrift Savings Plan (TSP) contributions. Miscellaneous fringe benefits include workmen's compensation, bonuses and awards, and unemployment programs.

For federal civilian employees not covered by either CSRS or FERS (normally intermittent and temporary employees), the Federal Insurance Contribution Act (FICA or Social Security) employer cost factor of 6.2 percent for retirement and disability and 1.45 percent for Medicare (or the current rate established by law)

should be applied. For retirement and disability, the rate is applicable for each employee only up to a maximum salary. Where such estimates must be made, care should be exercised that current tax rates are used and that the rates are applied only to wages below the maximum applicable salary.

The reader should note that the fringe benefit factors given for permanent Government employees are not comparable with those given for the private sector. The Government work force does not mirror the private work force but tends to consist of higher than average skill level employees. In the private sector, such employees tend to receive higher than average benefits and paid absences.

- Other Pay: This includes other compensation that does not earn fringe benefits. Some examples are night differential pay for FG employees, overtime, holiday pay, awards, and bonuses.

4. Total Personnel Costs

The fourth step is to translate annual labor requirements for each required skill into dollars. This is accomplished by multiplying the annual FTE's required (from step 2) by the appropriate total annual compensation per FTE (as determined in step 3) for each labor category and summing across all categories.

F. Airport Development Cost

Characteristics peculiar to the research and development and investment phases of airport investment projects require certain modifications/extensions to the life cycle cost model presented in Section III. above. The FAA has published draft guidance for the conduct of benefit-cost analysis of certain airport construction projects which addresses these considerations.[10] Portions of that guidance that relate to the specific characteristics of airport construction cost estimation are summarized here.

1. Planning and Research and Development Cost

Airport projects typically do not involve the development of new technology. They do involve long term land use commitments, require complicated financing packages, impact many peoples lives, and may have significant environmental impacts. Accordingly, their development phase costs tend to involve more planning and consultation and less research

[10] *FAA Airport Benefit-Cost Analysis Guidance*, Office of Aviation Policy and Plans, Federal Aviation Administration, Draft-June 2, 1997.

than equipment acquisitions or regulations. Typical costs in this phase of airport projects are indicated below. They include all costs to be incurred prior to beginning construction of the project under evaluation, except those costs that have already been incurred at the time of benefit-cost analysis or which must be developed in order to complete the analysis. Incurred costs are sunk costs and are not relevant for decisionmaking purposes.

- Any necessary research and development expenses associated with the project
- Project environmental assessment
- Detailed project design and engineering plans
- Coordination with regional development and transportation plans
- Arrangement of project financing
- Public outreach

2. Investment Cost

Airport investment phase costs typically involve much more land acquisition/development and specialized facilities construction than FAA acquisitions or regulations. Moreover, they may require cooperating investments by FAA, such as air traffic control facilities or instrument approach systems and other landing aids, and may involve purchase of specialized equipment. Airport investments may also entail significant transition costs which must be captured in the cost estimate. Airport investment phase costs requiring special consideration are:

- Land Cost: Land cost includes all interests in land that are acquired for the project, such as purchases, leaseholds, easements, air rights, mineral rights, etc.

- Construction Cost: Construction cost includes all expenses associated with the building of a new facility or the expansion, modernization, or refurbishment of an existing facility. Construction cost should also include any costs to expand, modernize, or refurbish any other portion of the airport or its infrastructure necessitated by the implementation of the project. Construction cost estimates are generally site-specific and should be developed based on engineering estimates. Table 4-6 summarizes airport construction costs. FAA should be consulted for cost estimates of facilities (e.g., air traffic control towers or precision landing systems) to be built by or in coordination with FAA.

- Equipment, Vehicle, and Provisioning Costs: Equipment, vehicle, and provisioning costs consist of items in addition to physical facilities that are required including the non-facility components of Airport Terminal Buildings. Vehicles include emergency

and maintenance vehicles required to service an expansion of airfield infrastructure. Provisioning costs are incurred for initial spare parts, special tools, and technical documents. Other items such as furniture would also be classified as equipment. All cost estimates should include any charges for transportation to the airport site.

- Transition Cost: Transition cost reflects the impact on airport operations of building and/or transitioning to the new project. This impact can be very large, particularly if the construction of the project leads to the temporary closure of major facilities of the airport. A runway reconstruction project will lead to the total or partial closure of the runway itself, and may cause the temporary closure of any runway intersecting it. Disruption and delay associated with the project may result in millions of dollars of additional costs to airlines, general aviation users, passengers, and others using the airport, and must be measured and included as an important cost element of the project.

TABLE 4-6

AIRPORT CONSTRUCTION COST ELEMENTS
Relocation of existing buildings and utilities at site
Site development
Clearing
Runway and taxiway facilities
Subgrade preparation
Paving and lighting
Shoulders and blast pads
Runway safety areas and other conformance to FAA design standards
Environmental mitigation costs (sound insulation, residence acquisition)
Precision landing system
Supplemental grading
Obstacle removal
Installation of precision system
Approach lights and MALSR
PAPI, NDB, and beacon
Air traffic control facility
ARFF facility
Air Terminal Building (ATB) access
ATB access taxiways
ATB access taxiway shoulders
ATB/cargo apron
ATB
Passenger terminal
Cargo terminal
Jetways
ATB Parking
Entry roadway and transit system
Water supply system (on- and off-site)
Sanitary sewer system (on- and off-site)
Storm water system (including water treatment)
Electric, gas, and telephone
Perimeter and security fencing
Fuel facilities
Airport maintenance facility